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Sofia Experimenter InterFace
PROJECT

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To: Walt Brooks
From: Mike Dix

Subject: SOFIA Experimeter Interface
Computational Requirements Assessment

SOFIA\FILE
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Introduction:

Airborne infrared observation opportunities are precious. Usually an investigator will spend a considerable amount of time and expense to insure his success because he knows that failure to achieve his objective will result in his taking a new place in the investigator queue for another chance. This may mean six months to a year before he has another opportunity for observation.

For this reason, investigators tend to be quite conservative, using autonomous instruments that are well tested and verified. They also tend not to rely on aircraft systems any more than necessary to avoid unforeseen occurrences.

However computer services and utilities are needed by the investigator. To minimize the risk for the investigator the guidelines for this assessment will be reliability of operation, redundancy where possible and well defined and solidly engineered interfaces. In addition the computational systems, status indicators and performance monitoring should be provided, during the observation time, so the investigator may knowledgeableably direct the aircraft team and his own experimenter team.

Types of Experiments

The anticipated instruments for infrared observation fall into four broad classes. They are the heterodyne spectrometers, photometers, arrays cameras and spectrometers.

The heterodyne spectrometers have relatively low data bandwidths, though newer instruments may have multiple channel outputs. This type of instrument may require chopping reference signals and preferably the investigator should have direct control over the chopping parameters. The amount of data collected usually is within the capability of the instrument to provide its own data processing and storage, though it may be desired by the investigator to use the aircraft computational system to provide redundant data storage. This class of instrument also requires high pointing accuracy for relatively long periods of time and the ability by the investigator to "tweak" the source onto the sensor.

The photometers also have relatively low data bandwidths, probably not exceeding 1 kHz as a single channel data stream. The photometer investigator does need both the chop and nod functions and may desire having direct control over those functions while observing. As with the heterodyne type instrument, this

Instrument also requires high pointing accuracy and capability also to "tweak" the telescope.

Array cameras have very high data bandwidths, though the trend in these experiments is for the investigator to provide high speed digital processing to reduce the data storage burden. If the aircraft computational system is to provide redundant data storage for the investigator it must be capable of handling 10 - 15 megabytes per second of 16 bit information. Or alternatively the aircraft system must be able to provide high speed processing for data compression. The camera or array investigator need chopping and nodding functions, preferably under his control. For extended observation periods the system must be able to provide field rotation. This is not a software function to be applied to the data, but is an actual field rotation of the focal plane image. The reason this is not a software function is that software can not compensate for viewing different reference images when chopping or nodding. (An extreme example of this would be when the field rotates a source appears in the reference beam direction.)

Spectrometers are relatively low data bandwidth instruments but require extreme pointing accuracy for long periods of time. They too required chopping and nodding functions. Pointing accuracy is critical with this type of instrument so it too must provide the investigator with the ability to align the telescope by "tweaking".

For each of these types of experiments the experimenter may desire to have an online display indicating the overall performance of his instrument. Camera and array instruments may use TV type displays, while the other instruments may be able to use an equivalent to a strip chart recorder presentation.

Though not present on the existing KAO system, the investigator may wish to have a means to annotate his experiment and store that information along with his data. A tape recording of the investigator team's conversation is also needed.

Operational Requirements

An observation requires the coordinated efforts of many people. Generally the sequence of operation is: the telescope is uncaged, pointed by means of dead reckoning to the approximate position of the target; optical tracking is commenced by the tracker operator who uses his knowledge of the starfields to point the telescope by a joy-stick at the required target and then engage automatic tracking; finally the investigator begins his observation adjusting the telescope position by small incremental steps, called "tweaking".

For this sequence of operation the telescope operator is in command of the facility, which then is transferred to the tracker operator, and then to the investigator. Because of the sequence of operation each person in command of the telescope should have

status indications of the actions taking by the person preceding him. This will allow the observer to be able to coordinate the activities of the telescope team when he is acquiring data.

Maximization of observing time is always a goal on each flight. This critically depends on the ability of the tracker operator to recognize star fields. The present tracker operator on the KAO has many years of experience and appears to have a natural talent for this job. Though it is fortunate we have such a skilled operator it may be appropriate to consider means whereby that position is not so critically dependent on an individual's skill.

It may be desirable to provide a summary TV display to the observer that indicates telescope position within its range of motion, a track mark indicating the beam location and temperatures in the optical path.

Though physical location of the investigators is not a computational requirement, the method of display is. The principle investigator generally will have a team operating his instrument. It is imperative the displays available to the principle investigator are arranged such that he can not only observe the status of the telescope but he must also be able to see what is being done with the instrument. For example, the PI may take charge of "tweaking" and insuring the target remains on the his sensor, but he also will want to observe the status of his instrument. (If headsets are used for SOFIA, it may be desirable to have a separate investigator trunk, a telescope operator's trunk, and an auxiliary trunk. If possible, communications between these trunks should not require any person to take his hands away from his operating station. (Maybe a push button which maintains communications across trunks as long as there is conversation, but when there is a gap of five seconds or so the trunk will return to the private mode.))

Environment

The primary environmental consideration for an airborne computational system is the presence of ground loops and extraneous signal sources. On even as small an aircraft as a Lear Jet the DC voltage difference for ground from the front of the plane to the rear is on the order of 0.3 volts and the AC voltage is on the order of 0.5 V rms. These voltages depend on what aircraft systems are actuated or what power is being provided to the telescope control system. Careful grounding and isolation of systems is required to prevent signals from entering the observer's instrument.

Where an interface is required from the observer's instrument to the computation system isolation should be provided. A possible means to accomplish this isolation is to have interface units mounted in the observer's instrument rack that are connected to the aircraft system, but provide isolation from the observer's signal chain. These interface units may take

many forms, they may be digital interface units adhering to the RS232 or IEEE 488 standard or may be a parallel 16 bit transfer bus. The interface unit may accept analog signals, providing multiplexing, analog to digital conversion, and isolation. Probably the most efficient manner of handling the isolation of experimenter and the aircraft system is to use low cost plastic fiber optics for communications.

A necessary installation feature for computers and instruments is the designation of a single point as ground and then referencing all instruments and systems to this point. Though this does not impact the computational requirements, it does affect their installation and location. Where ground referencing is not possible then isolation should be used.

When the observation requires basing the aircraft in a tropical environment the effects of humidity become a serious consideration both for the experimenter as well as the aircraft systems. The problem arises on the aftermath of a flight when equipment temperatures are cold and are subjected to the warm humid air of the tropics. This effect is cumulative in that all systems become more failure prone during the course of a mission. This shouldn't be too much of a problem for a plane as large as a 747 but some care should be taken to avoid condensation within the plane. The KAO project has purchased a ground air conditioner to provide cool dry air to the plane when it is on the ground. Such an installation would be desirable for SOFIA.

Experiment Installation

It would be expected that the same racks as used for the KAO will be those used for SOFIA. However, to ease installation and integration each of these racks should have a built-in interface module, powered by the aircraft computer system but able to accept isolated signals from the experimenter's equipment. This interface unit may also provide isolated logic levels or analog signals for the experimenters use. This interface unit may have many forms, allowing transmission of data by a number of communications standards.

Computation

At present, three levels of programming exist on the KAO. They are assembly language programming for instrument interfaces and controllers, real time interactive programs for the control of KAO functions and higher level programs for experiment support. For SOFIA these levels of programming would still exist but the proposed change from present design is to use "object oriented" programming for supervisory control and experimenter interface.

Object oriented programming has the feature of allowing quick changes in the functional operation of the telescope system and providing intuitive graphical displays to the operator. An

example of object oriented programming is the MAC operating system.

The higher level programs such as KNAV (flight planning program), KSP (star map program) and other utilities can be used in SOFIA without change. However if SOFIA were to use an object oriented supervisory system software interfaces would have to be installed with the commonly used flight utilities.

The trend in most observatories is to use "Small Talk" as a language as it is ideal for real time manipulation of instrumentation systems. By the time SOFIA is a reality it is likely that "Small Talk" or a similar object oriented program language will be the standard among experimenters.

There has been some discussion of using UNIX in a real time environment. Hewlett-Packard series 9000 system offers this capability, but it is my opinion that to put the entire SOFIA system under an operating system is unnecessary. An operating system is required for development and check-out and should be included in the ground simulation system, but it may add complexity and cost to the flight system. Non real-time functions performed by SOFIA, of course, should be supported by an operating system, preferably UNIX.

There is a need for a "data sponge" to archive the experimenter's data. This is a limited function computer which looks very much like a printer. It accepts data and a strobe and records the data available from the experimeter. Data formatting and header information is the responsibility of the experimeter. The recorded data may not be retrieved during flight, but is made available when the tapes (or other recording media) are processed by the ground system.

Heritage

The KAO has a number of systems that are directly applicable to SOFIA. They are:

1. Water Vapor System

This is an interferometric sensor for determining water vapor by means of infrared spectrum. This system tells the observer what obscuration existed during his observations.

2. Strap Down Gyro Reference System

This system provides information to the telescope system to establish the azimuth, elevation and roll on the telescope referenced to the aircraft platform for accurate initial pointing.

3. Video Cameras

Two camera systems are being developed for the KAO using the latest ISIT technology available from Cohu Electronics. Though both of these cameras, one for acquisition, the other for tracking, will require new optical systems for SOFIA the cameras will give state of the art performance.

4. Focal Plane Video System

At present the focal plane video system is proposed but money has not yet been made available. Most of the elements of the system have been identified and are either built or commercially available. The heart of the system is a thermoelectric cooled CCD camera capable of producing a picture 4 times per second. The mechanical stages for centering are commercially available as is the filter wheel. The optics to place the camera at the optical focal plane had not yet been manufactured. Estimated costs for the system are: Camera (from University of California Santa Cruz) \$75K, Controller for image rotation and interface to system (Yerkes Observatory) \$33.5K and optics consisting of transfer lenses, dichroic mirror and reticle \$135K.

5. Telescope Inertial Pointing System (TIPS)

This is a digital system that combines navigational data, aircraft attitude, rate outputs from the telescope gyroscopes and time to provide a boresight position in right ascension and declination..fi a:sofydata

Expected Data Sources

This is a summary of KAO data sources and expected data sources for the SOFIA to aid in design of the experimenter interface facilities.

In-flight Aircraft Data:

1. Navigational data

- a. Latitude
- b. Longitude
- c. Heading
- d. Wind speed
- e. Wind direction
- f. Time
 - 1) Zulu time
 - 2) Time to end of the observation
 - 3) Time to the end of flight

2. Telescope Status

- a. Cage/Uncage (indicates control by telescope operator)
- b. Manual/Track (indicates control by tracker operator)
- c. Observe (indicates control by observer)

3. Environmental Data

- a. Water vapor; zenith
- b. Water vapor; line of sight
- d. Outside air temperature

Tracking Data

1. Video presentations

- a. Guide scope ?
- b. Star map
- c. Tracker

2. Track Data

- a. Track error (azimuth and elevation)
- b. Track Quality (rms of azimuth and elevation deltas)
- c. Track Mode
 - 1) Centroid tracking
 - 2) Correlation tracking
 - 3) Guide Scope/Star map correlation tracking
- d. Field rotation angle

Telescope Data

1. Pointing Data

- a. Azimuth, gyro derived
 - b. Elevation, gyro derived
 - c. Line of Sight (roll), gyro derived
 - d. Calculated ascension/declination
 - e. Azimuth relative to aircraft
 - f. Elevation relative to aircraft
 - g. Line of sight (roll) relative to aircraft
- ### 2. Temperatures

- a. Primary temperature
- b. Secondary temperature
- c. Tertiary temperature
- d. Head ring temperature
- e. Barrel temperature
- f. Nysmith adapter temperature

3. Mechanical

- a. Strain guage measurements
(for airflow induced distortion)
- b. Wideband acceleration at experiment interface
(for microphonics monitoring)

Secondary Mirror

1. Dynamic Parameters

- a. Waveform (square, triangle, sawtooth, raster)
- b. Amplitude
- c. Frequency
- d. Origin (x,y for secondary motion)
- e. Axis (angular direction)
- f. Damping
- g. Reference phase

2. Static Parameters

- a. Focus position
- b. Image motion compensation position (x,y)

Telescope System

1. Air Bearing System

- a. Air Pressure
- b. Pump status

2. Telescope Cooling

- a. LN supply
- b. Valve status
- c. Chamber and Telescope temperatures
- d. Chamber Humidity
- e. Air dryer status

3. Error System

- a. Position limits, includes limit warning.
- b. Torquer overload
- c. Telescope acceleration (wind induced)
- d. Door & fence failure
- e. Power system degradation / failure
- f. Observer computer failure

Health Checks

1. Communications

- a. Supervisor / controller data links
- b. Observer / Supervisor data links
- c. Instrument network data links

2. Equipment

- a. Supervisory Control system
- b. Navigation system
- c. Data Acquisition
- d. Servo system (small signal random noise test)

3. Environment

- a. Equipment temperatures
- b. Cabin Temperature
- c. Cabin Humidity
- d. Ground cooling system status

Observer Data

1. Video Presentations

- a. Star Map (optional boresight overlay)
- b. Star Map with nod points
- c. Guide scope with boresight overlay
- d. Guide scope with nod point overlay
- e. Guide scope with star map overlay
- f. Tracker scope
- g. Tracker display
- h. Flight track (optional computed flight track overlay)

2. Data Presentations

- a. Strip chart instrument display
- b. x,y,z data display
- c. Data spectrum display
 - 1) strip chart
 - 2) tabular
- d. Autocorrelation (for last 'n' minutes)
 - 1) Strip chart
 - 2) Tabular
- e. Last 'n' minutes of data
 - 1) Strip chart
 - 2) x,y,z data display
- f. Alternate experiment data
(for case where two or more reduction programs are in use.)

Pilot Data

1. Flight Track Presentation

- a. Video presentation of pitch, roll and yaw relative to computed values
- b. Audio alarm indicating imminent loss of track.

2. Telescope Status

- a. Visual display of telescope status
(cage/uncage, manual/track, observe)
- b. Boresight position relative to allowed range of motion.
- c. Autopilot or telescope control of heading.

